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CONTENTS

CORRELATED CHARACTERISTICS OF TERMITES ATTACK WITH HIGH-RISE BUILDING CONDITION INDEX

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ABSTRACT

This research aimed to characterize termites attack in high-rise building. The procedure of this research consisted of three steps: mapping of termites in outdoor location, assessing the similarity of termite colony in the indoor and outdoor location, and assessing the condition index of building. The first two steps concluded that there were two species of termite around the building, Macrotermes Gilvus and Coptotermes Curvignathus. Deeper observation showed that Coptotermes Curvignathus had attacked the building to its top. Foraging activities of Coptotermes Curvignathus in the building was started from water pipes or plumbing because water source with constant supply of moisture is mandatory for the survival of those termites. The conclusion showed that the lowest condition index of building is in Building 1 and the highest condition index of building is in Building 4.

Keywords: Termites attack, Coptotermes Curvignathus, Macrotermes Gilvus, Foraging activities, Condition index of building.

INTRODUCTION

Since mid-1970s, real estate has been one of the key sectors of the development and production in various objects of urban infrastructure. In Jakarta, there are now over 800 high-rise buildings with more than eight floors. Those buildings basically act as office buildings, hotels, and apartments. Some of those high-rise buildings are Wisma BNI Building, Trade Tower Building, Artha Graha Building, Orchid Garden Apartments, and other buildings. Jakarta Tower Building, even though is still in concept design, also categorized as high-rise building with 125 floors and height of 395 m. Since the beginning of year 2005, the development and construction of high-rise building for living (apartment) has been very popular in Jakarta lately.

Unfortunately, some constructions of high-rise buildings in big cities have caused negative impacts by making the land narrow and also disturbed the habitat of termites (Nandika et al. 2003). The condition of narrow land in cities contributes to a change in the realization of green environment plan from green landscape to roof garden. Despite its function to provide the greenery area, roof garden also causes the risk of becoming new habitat of termites because of the movement of termites from soil under the ground to soil in roof garden (Surjokusumo 2005).

This problem becomes important along with the enforcement of Law of Indonesian Republic number 28 year 2002 regarding the building, particularly on article 37 point 3 and article 37 point 5, which mentioned about the importance of controlling termites attack on building. In reality, building maintenance is a combination of various actions

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taken to maintain the items to the condition in which the items are always in a state of functioning and ready for use. Knowledges and technologies of maintenance, namely terotechnology, are needed to achieve it (Juwana 2005).

On certain condition, maintenance level, treatment level, and building inspection level can be estimated precisely. The science of pathological building can be used to assess the construction conditions or the "diseased" buildings by identifying its causes, symptoms, and behaviours (Sebastian 2003).

Research purposes are as follow:

1. To know the route and the factor influenced the roaming range of subterranean termite Coptotermes Curvignathus in high-rise buildings.
2. To identify the factors causing the damage in construction components of high-rise buildings.
3. To evaluate the condition of construction component after the attacks of subterranean termite Coptotermes Curvignathus.

The benefit of this research is to obtain the information regarding the activities of Coptotermes Curvignathus termites and its impact in the construction of high-rise buildings. In addition, the results of this research are expected to be the reference in constructing the high-rise buildings, especially for the choice of building materials and construction site where the bio-deterioration factors such as the attack of termites has not been accounted yet.

RESEARCH METHOD AND PROCEDURE

Method

This research was conducted in 15 buildings in South Jakarta used as the apartment and hotel as shown in Figure 1. Science Biological Laboratory in Bogor Institute of Agriculture was also used as research place. The research was conducted for 16 months.

Materials and Equipments

The materials used in this research were the blueprint and images of the buildings, visual data of 15 buildings (especially for Building 1, Building 3, and Building 4 which had been severely attacked by termites), 178 pieces of pine tree wood with dimension of 1x2x30 cm as the bait, and 42 pieces of air-dried pine wood (with dimension of 1x2x10 cm and have been smeared by 0.5% hexaflumurón to lure the termites) that will be used in the observation area in 42 points within the buildings. For the observation in Building 3 and 4, nine boxes with rolled tissue inside smeared with 0.5% hexaflumurón were used to lure the termites.

The equipments used in the research were visual data recorder, data observation recorder for existing structure component and subcomponent, tool for storing and observing the termites, flashlight, pots/plastic tubes, alcohol, tissue boxes, saws, PVC pipes, plastic bags, Petri dishes, microscopes, and a tool to determine the humidity in the building. A survey using table entries was conducted to obtain the data related to the technical condition of buildings, utility networks, and location of dilatation structure that divided the building.

Figure 1. The apartments and hotels in South Jakarta and the mapping of termites

PROCEDURE

Bait Installation and Termites Identification

A sum of 150 baits with dimension of 1x2x30 cm were painted red on its upper side to locate the baits easier during the observation. The baits were installed on dampy ground or near the plant roots on the building area (soil on the fifth floor) and entire lower part of all the 15 buildings. Each bait was vertically buried into the soil for 25 cm depth, leaving only 5 cm of the baits that appear on the surface. The distance between each bait was set to be about 5 m. Observations would began in 2 months after the baits were installed, then the captured termites on the bait were collected and put into plastic pots to be identified in the laboratory.

Colony Identification

<u>Observation on ground soil in Building 1, 2, 3, and 4</u>

The soil around the baits in Building 1 and 2, which attacked by the termites, were dug in a 5 cm diameter and a depth of 23 cm. A PVC pipe was vertically inserted into the hole to limit the formed room in the hole. The hole was called the observation station. There were 28 observation stations installed in Building 2. A stick of air-dried pine wood was placed into the PVC pipe, then the top part of the PVC pipe was sealed with plastic and the pipe was covered in soil for 4 months. Every 2 weeks, the captured termites were collected in a container to test whether they are from the same colony or not. Some of them were identified in the laboratory. For Building 3 and 4, the bait was smeared with 0.5% hexaflumuron first, then buried in the appointed stations. The total number of stations in Building 3 and 4 were 42 stations. The observations were conducted for 5 months. The process of capturing and identifying termites was done every 2 weeks, just as in Building 1 and 2.

Observations inside Building 1, 3, and 4
In Building 1, the observations were done based on the reports from the management of the buildings. Nine units of observation stations were prepared for Building 3 and 4. The observation stations used 0.5%-hexaflumuron-smeared tissue papers which placed in boxes mounted on the wall of the upper floor, middle floor, and ground floor. The tissue boxes were left for 5 months. Every 2 weeks, those boxes were observed to find out the similarities in the colonies of termite. The captured termites were collected in the same container as the termites collected from different observation stations. Those termites collected in the container were going to be identified in the laboratory.

Building Condition Index
Field observation
The steps for field observation to know the condition index of the building were as follow:

- Conduct the observation towards the construction condition of building in each floor to anticipate the termite colonies living in the interior area of building's construction.
- Investigate the location of the damaged construction building caused by termites attack and identify the type of damage caused by either the factor of planning, construction, user's carelessness, maintenance system, or the utility of building's material.

Data analysis
Data analysis was done by conducted a weighting for each construction element (cost, function, and maintenance), subcomponent, sample unit, component parts, building components, and building systems in a building in an integrated way and determine the priority of construction component hierarchy as a pathological building. The calculation of condition of the building was done by using the condition indexes based on the Engineering Management System (EMS), which was developed by United States Army Construction Engineering Research Laboratory or USACERL (Uzarski and Burley 1997). This calculation used the sampling techniques, which examined the buildings throughout its components. Its value was determined based on the combination of type, level, and quantity of destruction.

In this research, the types of damage associated with termites attack were the wrinkled surface, hair-size cracks, gaps, holes, and loose or torn materials. Each type of damage determined the extent of damage and its quantity. The index calculation procedure can be seen in Figure 2. The first process began with the index calculation for each subcomponent unit of the samples. Combined index for the various hierarchies were also calculated.

Subcomponent index (CIs) was calculated from the reduced weight of density quantity model. The models related to the deterioration level on the difficulty, dangerous, and amount of damage were found along the condition survey. After the subcomponent was checked and the condition index was determined, then the condition index of sample unit was also determined. Next, sample unit for each component was combined into the component section condition index (CSCI) based on its size. The next processes were going in the same pattern until building condition index (BCI) was obtained.

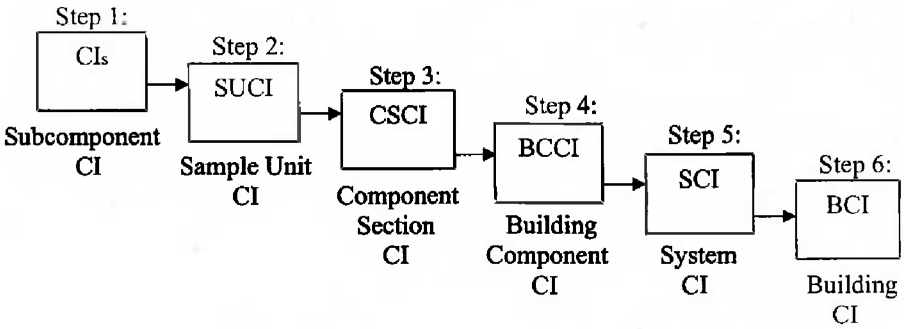

Figure 2. Flowchart of BCI calculation (Uzarski and Burley 1997)

Data obtained for the estimation model of components (CSCI) will be analyzed statistically to see if there was termites attack occured in room and floor of the apartments and hotels in South Jakarta. The general model used for data analysis to see the influence of termites attack towards the component section condition indexes was the randomized complete block design, as shown in the equation below (Sudjana 1982).

$$Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij} \qquad (1)$$

where: Y_{ij} = Value from building component condition index
μ = Average condition index
τ_i = The effect of index floor condition on the
β_j = The effect of index condition on a room
ε_{ij} = The effect of experimental error in the component condition index

RESULTS AND DISCUSSION

Mapping of Termite's Colony

This research showed that the species of termite exist in the apartments and hotels are Macrotermes Gilvus and Coptotermes Curvignathus. Macrotermes Gilvus termites exist in the area around Building 1, 7, 9, 11, 15, and 17. Meanwhile, the Coptotermes Curvignathus termites were detected in the surrounding area of Building 1, 2, 3, 4, 9, 11, and 15. Both termite species were found on the areas around Building 1, 9, 11, and 15 whereas in area of Building 6, 8, 10, 12, 14, and 16 termite colonies weren't found.

Based on the results of research, the two termite species have a fairly large region for each colony. In general, the colony of Coptotermes Curvignathus termites seemed to have broader ranges in term of its foraging activities than the colony of Macrotermes Gilvus termites. This result also indicates that the species of Coptotermes Curvignathus termites has larger population in each colony more than Macrotermes Gilvus termites.

The Route of Termites Movement in Building 1 (Apartment), Building 3, and 4 (Hotel)

Outside the building

The result of investigation showed that both species of Macrotermes Gilvus and Coptotermes Curvignathus termites were found in Building 1. But, only Coptotermes Curvignathus species was found in area around Building 3 and 4. The similarity between the colonies of termite in Building 3 and 4 was indicated by no aggression shown between the two colonies that were put together in one container. Meanwhile, the same process wasn't conducted in Building 1 because most of the implanted wood baits were missing although the replacement had been implanted.

Usually, termites do not attack living plants, except for most of Coptotermes Curvignathus termites (Nandika et al. 2003). Good treatment to the plants in apartments and hotels area really supported the movement activities of Coptotermes Curvignathus termites in search for the food source. The limited movement of Macrotermes Gilvus termites was because of dry leaves and dead plants concentrated in several points of apartments and hotels area.

Inside the building

Termites found in Building 3 and 4 were from Coptotermes Curvignathus species. Termites from Building 3 and 4 that were put together in one container didn't attack each others, proving that the termites came from one colony. Tissue bait wasn't implanted in Building 1 because most of the apartment residents had done termites extermination individually and changed the material that was damaged by the termites attack. From the visual data of Building 1, roaming routes of termites were only found on the 23^{rd}, 25^{th}, and 29^{th} floors, which were suspected to be the roaming routes of Coptotermes Curvignathus termites.

The route of termite's vertical roaming in the apartments and hotels buildings in South Jakarta was started from clean water plumbing that went through the basement, which had high humidity and low lighting. The condensation on air conditioner pipes, the existence of clean and dirty water pipes, leaking gutter, and the location of plants at the upperside of the terraces made a good habitat for the termites. Termites attack that occured until the highest floor of the apartments and hotels buildings showed that the roaming ability of termite Coptotermes Curvignathus wasn't affected by gravitation.

The route of termite's horizontal roaming was done by going into the next door room (inter-room) through wood plints attached on the connecting corridors and in the rooms between one unit to another. To reach every room in each floor, the termite colony could directly go into the humid parts of the room like bathroom, washing room, and the surroundings. This was also supported by the relatively low activities of residents inside the apartments and hotels (living time there was only up to 8 hours/day at most), causing the lack of vibration from the residents as the resistor of termites roaming activity. Besides that, small holes around 1-2 cm at the dilatation system (the separator of building structure), holes between cemented walls and ceramic floor covers, and also the part of wooden sills that nudged closer with the ground were also the entrance access for termites to apartments and hotels.

<u>The relation between termite colonies outside and inside the buildings</u>
Termites found outside the building apparently had similarity with termites found inside the building. This was proven by no aggression shown between each colony when they were put together in one container. The colony verification of Coptotermes Curvignathus termites was only done in Building 3 and 4, but this had proven enough that the termite colonies found in the two buildings came from one colony that considered as a big colony.

Building Condition Index

<u>Condition index of sample units</u>
Condition index of sample units was analyzed from the walls and ceilings in Building 1, Building 3, and Building 4. The floors were not analyzed because they contained no cellulose element as termite media.

The research result showed that the wall of living room or dining room in Building 1 had the lowest condition index with the score of 43.26 (included in "enough" condition category) and the highest condition index was in Building 4 with the score of 96.98 (included in "best" condition category). The lowest condition index of wall was found in bedrooms in Building 1 with the score of 38.10 (included in "poor" condition category) and the highest condition index of wall was in Building 4 with the score of 97.26 (included in "best" condition category). The lowest condition index of bathrooms or Water Closets was in Building 3 with the score of 47.72 (included in "enough" condition category) and the highest condition index of bathrooms or Water Closets was in Building 4 with the score of 98.80 (included in "best" condition category). Meanwhile, condition index of corridor's wall in Building 1, 3, and 4 were 98.46, 98.46, and 99.12, respectively (included in "best" condition category), as seen on Table 1.

Table 1. Wall and ceiling condition index of sample units in Building 1, 3, and 4

Building	Living rooms/ Dining rooms		Bedrooms		Bathrooms		Corridors	
	Walls	Ceilings	Walls	Ceilings	Walls	Ceilings	Walls	Ceilings
1	43.26	100	38.10	100	54.12	100	98.46	100
3	65.35	100	80.22	100	47.72	100	98.46	100
4	96.98	100	97.26	100	98.80	100	99.12	100

<u>Condition index of component parts</u>
The discussion of condition index in these apartments and hotels was analyzed from the condition index of component parts, which are the apartment rooms in each floor.

Research result showed that the condition index of living rooms or dining rooms was the lowest in Building 1 with the score of 48.61 (included in "enough" condition category) and the highest condition index of living rooms or dining rooms was in Building 4 with the score of 67.57 (included in "good" condition category). The lowest condition index of bedrooms was in Building 1 with the score of 44.22 (included in "enough" condition category) and the highest condition index of bedrooms was in Building 4 with the score of 72.00 (included in "better" condition category). Condition index of bathrooms was the lowest in Building 3 with the score of 46.17 (included in "enough" condition category) and the highest condition index of bathrooms was in Building 4 with the score of 80.52 (included in "better" condition category). Index condition of corridors in Building 1, 3, and 4 were 56.71, 77.49, and 77.80, respectively, as seen on Table 2.

Table 2. Condition index (CI) and condition category (CC) of component parts (rooms) in Building 1, 3, and 4

Building	Living rooms/ Dining sooms		Bedrooms		Bathrooms		Corridors	
	CI	CC	CI	CC	CI	CC	CI	CC
1	48.61	Enough	44.42	Enough	54.1	Enough	56.71	Good
3	55.75	Enough	64.11	Good	46.17	Enough	77.49	Better
4	67.57	Good	72.00	Better	80.52	Better	77.80	Better

<u>Condition indexes of components, systems, and buildings</u>

For the condition index of apartment and hotel components, apartment units and hotel rooms in each floor were analyzed. Two units were taken randomly in each floor. Condition index of systems were the condition index of the systems in each floor of Building 1, 3, and 4. Condition indexes of building were the overall condition index of Building 1, 3, and 4.

The research result showed that the condition indexes of components, system and buildings in Building 1 were the lowest in Building with the score of 38.91-60.75, 39.06–60.25, and 50.22 respectively as seen on Table 3 whereas the condition indexes of components, system and buildings were highest in Building 4 with the score of 72.69-73.69, 72.89-73.55, and 73.19, respectively.

Tabel 3. Condition index and condition category of components, systems, and buildings in Building 1, 3, and 4

CI and CC	Building 1	Building 3	Building 4
Components (Apartment Units)	38.91-60.76 (poor-good)	57.98-63.92 (good)	72.69-73.69 (better)
Systems (Floors)	39.06-60.25 (poor-good)	58.36-63.77 (good)	72.89-73.55 (better)
Buildings	50.22 (enough)	60.10 (good)	73.19 (better)

From the research result, the occupancy level of Building 1 was higher compared to the occupancy level of Building 3 and 4. Higher occupancy level has caused higher building operational activities that used clean water through plumbing and air conditioner pipes. Clean water, dirty water, and air conditioner pipes plumbing was the source of humidity needed for the climate and medium of termites habitat. So, the usage of buildings utilities would be the entrance route of termites into the buildings.

Relationship between termites attack and condition indexes

The result of variance analysis toward the damage caused by termites attack showed that there were significant differences on floors (1^{st} - 30^{th} floors) and rooms (living rooms or dining rooms, bedrooms, bathrooms or water closets, and corridor) for Building 1 as seen on Table 4. This explained that the higher the floor in Building 1 was from ground surface, the lesser the damage caused by termites. There were also significant differences of damage caused by termites attack in each room in Building 1 where the highest damage was in bedrooms and the lowest damage was in corridors.

Table 4. Variance analysis toward condition indexes of component parts caused by the attack of Coptotermes Curvignathus termites in Building 1

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	Observed F	F Table	
					5%	1%
Average	1	312,875.26	312,875.26	-	-	-
Floor	29	2,816.38	97.12	2.38**	1.60	1.94
Room	3	9,016.58	3,005.53	73.66**	2.71	4.02
Error	87	3,549.88	40.80	-	-	-
Sum	120	328,285.10	-	-	-	

**: significant at 1% level

Variance analysis in Building 2 showed significant difference only in each room, while the difference in each floor was not significant (seen on Table 5). This showed that damage in Building 2 caused by termites attack was not significant for every floor, for both far and close range from the ground surface. Rooms with the highest damage were the bathrooms or water closets. Rooms with the lowest damage were the corridors.

Table 5. Variance analysis toward condition indexes of component parts caused by the attack of Coptotermes Curvignathus termites in Building 3

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	Observed F	F Table	
					5%	1%
Average	1	489,234.11	489,234.11	-	-	-
Floor	32	1,018.59	31.83	1.26^{ns}	1.57	1.89
Room	3	17,460.38	5,820.13	230.64**	2.70	3.98
Error	96	2,422.50	25.23	-	-	-
Sum	132	510,135.59				

ns: not significant

**: significant at 1% level

Variance analysis in Building 4 showed no significant difference on each floor while the the analysis on each room showed a significant difference (seen on Table 6). The damage caused by termites attack was the highest in living rooms or dining rooms while the lowest damage was in bathrooms or water closets. There was no difference on each floor, whether the floors are far or close from the ground surface showed the same damage caused by Coptotermes Curvignathus termites. This occurred because the research in Building 4 was only done up to the tenth floor as the apartment had changed its function into hotel and the building was under demolition and renovation.

Table 6. Variance analysis toward condition indexes of component parts caused by the attack of Coptotermes Curvignathus termites in Building 4

Source of Variation	Degree of Freedom	Sum of Square	Mean Square	Observed F	F Table	
					5%	1%
Average	1	221,846.13	221,846.13	-	-	-
Floor	9	1.50	0.17	0.33^{ns}	2.25	3.14
Room	3	1,014.02	338.01	656.58**	2.96	4.60
Error	27	13.89	0.51	-	-	-
Sum	40	222,875.55	-	-	-	-

ns: not significant
**: significant at 1% level

The common type of damage that occured in Building 1, 3, and 4 were the wrinkling of material surface and hair crack found in cellulosed material. The direct loss was only caused by termite colony from Coptotermes Curvignatus species and didn't include the indirect loss to renovate the damaged areas and the surroundings. The calculated damage of cellulosed building material was only about 8 - 10% of the whole apartment building cost.

Harris (2003) said that in many modern structures, termites didn't only damaged the construction material of a building but also the interior material such as wooden floor, separator wall panel, wallpaper, wallboard, furniture, and backside fibers of synthetic carpets. This also happened in each apartment unit/ hotel room observed in the research location. This indirect damage would made the previous percentage become greater.

The Pathology of Apartment and Hotel Buildings

The observation of material damages occured by three factors, which were acceleration, mitigation, and substitution. Those three damage factors could occur again in 3 - 4 years span. So, the buildings should be renovated again. In this case, building maintenance staffs should have more detailed knowledge about the condition of building structure, building utility, and cellulosed material to minimize the damages.

The rate of destruction of cellulosed material would occur rapidly, especially at apartment buildings that had been the property of the residents. This happened because the maintenance staffs didn't directly maintain the rooms in apartment units. In hotel buildings, the maintenance area was the whole building, included the inner parts of hotel rooms unit.

Terotechnology

Terotechnology was the discussion analysis that included technology and economy factors. According to Juwana (2005), the calculation of operational and maintenance cost of high-rise building was 25% of the total income from apartment sale value and hotel rooms tariff. From the research, the building maintenance in these apartments and hotels in South Jakarta was included as the usage of electricity and water, building equipment maintenance, work safety, environmental control, cleaning, and gardening works.

The loss caused by termites attack in Building 1, 3, and 4 didn't brought damage to the structure system but only to construction with cellulosed material and quite significant loss in term of convenience and safety of the residents. The calculation of damage caused by termites attack was equivalent to roof and yard cleaning cost, which was around 2% a month. So, it was in line with the depreciation of building without maintenance.

CONCLUSION AND RECOMMENDATION

Conclusion

In general, the research result in the assessment of condition indexes showed that the damage caused by termites attack was higher in Building 1 than in Building 3 and 4. The damage caused by the existence of Coptotermes Curvignathus colonies in Building 1 was only handled by the residents (unintegrated handling) in each apartment units which eased the growing of new termite colonies with suplementer reproduction. In Building 3 and 4, the damage caused by termites attack was still handled by maintenance staff in an integrated way.

The assessment of building pathology was done by observing the material damage caused by the choice of initial design shape from system module of construction structure that still used the same kind of materials (cellulosed materials). From terotechnology assessment, the material damage clearly affected the economical factor, safety and convenience with damage value equivalent to roof and yard cleaning cost for each month.

Recommendation

The stage of termites attack's prevention and control should be started from ground surface around the building. The treatment mustn't been done in the beginning of construction work, but after the apartments and hotels were built to prevent the termite colony entering the building and made new habitat with suplementer reproduction. Besides that, the maintenance staffs should add work tasks to prevent and control the termites with the prevention and control method using bait system tools.

REFERENCES

Harris, S. Y. (2001). *Building pathology: deterioration, diagnostics, and intervention.* John Wiley & Sons, New York.

Juwana, J. S. (2005). *Panduan sistem bangunan tinggi.* Erlangga, Jakarta.

Nandika, D., Rismayadi, Y., and Diba, F. (2003). *Rayap: biologi dan pengendaliannya.* Muhammadiyah University Press, Surakarta.

Sebastian, A. (2003). *Construction pathology.* Sebastian Engineering and Investigation Services, Seattle.

Sudjana, (1982). *Desain dan analisis eksperimen.* Tarsito, Bandung.

Surjokusumo, S. (2005). *Perkembangan aspek regulasi pengendalian serangan rayap pada bangunan gedung.* Seminar Nasional Universitas Negeri Semarang, Semarang.

Undang-Undang Republik Indonesia No. 28/2002. (2003). *Bangunan gedung beserta penjelasannya.* Citra Umbara, Bandung.

Uzarski, D. R. and Burley, L. A. (1997). Assessing building condition by the use of condition indexes. *Proceeding Paper, Infrastructure condition assessment: art, science, and practice*, ASCE, Boston, United States.